June 30, 1999

Compendium of Current Positive Train Control Projects

This document contains short descriptions of the system design or architecture and functional capabilities of the various Positive Train Control (PTC) projects in place or planned for the near term. The Table at the end of this document summarizes these projects. The short descriptions were requested of the Association of American Railroads (AAR) at the PTC Rail Safety Advisory Committee (RSAC) meeting in March 1998. As the PTC projects are tested and implemented, this compendium will be updated.

Union Pacific/Burlington Northern Santa Fe Positive Train Separation Pilot

System Design

The UP/BNSF Pilot in the Pacific Northwest is a non-vital overlay to existing train control systems in all types of territory. The physical topology for the pilot is shown in figure 1. Central dispatch (PTS Server) provides movement authority to train and the train reports location to the PTS Server. The location system uses differential GPS, odometers and rate gyro to determine location. Enforcement of speed and movement authorities is on-board the locomotive. The wireless portion of the data link between dispatch and the locomotive is both 160 (BNSF) and 900 MHz (UP). Interoperability is one of the key objectives. BNSF and UP have established a digital data link through their respective dispatch centers that allows BNSF dispatch to route movement authorities to UP trains and vice versa.

Functional Capabilities

The PTS system enhances railroad safety by enforcing movement authority and speed restrictions for PTS equipped trains. The PTS system accomplishes this through three segments: the Server Segment, the Locomotive Segment and the Communications Segment. The Server Segment is logically centralized, although it may be physically distributed. Its primary function is to determine the PTS enforceable movement authority and speed limit for any train under PTS control. This information is transmitted through the Communications Segment to the Locomotive Segment located on-board the controlling locomotive of each train. The Locomotive Segment enforces movement and speed limits by stopping the train before a violation occurs. A functional diagram of the PTS system is shown in Figure C-2.

Figure C-1. Physical Topology

Figure C-2. Functional Diagram

The purpose of PTS is to enhance railroad safety through enforcement of movement authority and speed, with some additional collision protection features and optional on-board display capabilities. The PTS system does this while maintaining current levels of operational productivity and providing a growth path to precision train control and advanced computer-aided railway management capabilities.

In PTS operations, trains continue to be controlled by fixed block signals, track warrants, work authorities, and other types of conventional movement authorities originating in the CAD system. Overlaid on these displayed authorities, and derived from them, are PTS authorities defining enforceable limits of movement for equipped trains. In CTC, 9.14 and 9.15 territory, the PTS authority is based on CAD Authorities conveying route information (track authorizations and switch settings), generally extending between two control points. The PTS system does not require any knowledge of *intermediate* signal aspects. In Track Warrant Control (TWC) territory, the PTS authority is based on a train's current track warrant.

The PTS Server generates PTS authorities automatically. Except in special cases (such as joint authorities), the enforceable authorities for two trains are not allowed to overlap. While PTS authorities generally coincide with the underlying CAD authorities, in certain cases the requirement for non-overlapping PTS authorities means that the PTS authority is more restrictive than the CAD authority. In a following move, for instance, the enforceable authority for the following train is limited by the leading trains' rear-end position, even if the CAD authorities for the two trains overlap. The PTS system continuously monitors the position of the leading train so as to incrementally extend the following train's PTS authority.

The PTS system protects trains against collision by enforcing PTS authorities. The on-board PTS system monitors a train's position in relation to its enforceable movement limits and continually recalculates the braking distance to confirm that the train can safely stop within the limits. If a train approaches the point at which a safe stop within the movement limits would be impossible, the onboard system responds first with a warning and then, if the crew takes no action, with an application of braking to stop the train at the end of its PTS authority limit. The PTS architecture ensures that lack of communications will never result in a safety critical situation.

The algorithm that determines safe braking distance is instrumental to maintaining present levels of productivity. This algorithm incorporates detailed consist data and track profile data to improve the accuracy of the calculation and so keep required headways to a minimum. The pilot PTS system will only address trains that have all their motive force applied at the head end. However, the system architecture will take into consideration the need to include helper locomotive operations and remotely controlled distributed power (e.g., LOCOTROL) in a production system.

Although the PTS system makes allowance for most train movement scenarios, absolute protection cannot be provided in every case. The more prominent among non-protected cases are those involving combinations of PTS equipped and unequipped trains.

Besides movement authority, the PTS system enforces speed restrictions of various types. In addition to enforcing track speed, the PTS system enforces speed restrictions associated with track bulletins, track warrants, work authorities, bi-directional movement authority, and train-specific characteristics.

Passenger/Freight Applicability

Nothing in the design of PTS specifically limits its applicability to passenger or freight operations. As with all PTC systems the speed of passenger trains puts a burden on the communications platform and must be accounted for in the selection.

Technical Readiness

The fourth and final release of PTS has been tested. The project is currently suspended.

Amtrak Incremental Train Control System (ITCS) Project

Functions

ITCS provides the basic safety functions of preventing train-to-train collisions, protecting against overspeed, and providing protection for roadway workers operating under dispatcher authority. In addition, it provides advance start capability for grade crossing warning systems.

Architecture

The basic components of ITCS are wayside servers, wayside interface units (WIUs), the On-Board Computer (OBC), and a dispatch terminal used only for managing temporary slow orders. ITCS uses a totally distributed architecture based on an existing signal system providing the foundation for authority information. The system takes its authorities from the signal system, which protects fixed blocks based on track circuit occupancy. Track, signal and switch statuses are monitored at the wayside using WIUs which collect the necessary data from each affected location and pass it to a server responsible for data collection in a given area. Typical coverage of an individual server is 4 to 8 miles of track, spanning as many individual signals, control points and crossings as are present in that segment. Server coverage area is limited by radio coverage, both train-to-wayside radio and an independent wayside local area network (WLAN), which uses unlicensed spread spectrum radios to gather data from the outlying WIUs into the server.

The OBC carries a track profile database containing GPS coordinates and all relevant targets, which the train must respond to, including all fixed and temporary speed restrictions. Using GPS receivers and axle tachometers to track its location, the OBC continually calculates its position relative to each target and determines if a speed reduction will be required.

Authorities for train movement originate with the dispatcher or CAD by requesting routes through the normal CTC process, resulting in controlled signals displaying a permissive aspect. The wayside server, based on data collected from individual locations through the WLAN, periodically broadcasts the status of each object in its territory. These include signal indications, switch positions, certain track circuit statuses and several statuses from each crossing where advance start operation is used. Each status broadcast contains the status of all objects in the WLAN area and broadcasts are repeated at intervals of approximately 6 seconds. Any train in the area will receive the broadcasts and determine which statuses are relevant to its own location. Each signal indication carries an implied target speed, which is used by the OBC to calculate a braking profile to reach that speed. When any braking profile is close enough to be within 30 seconds of requiring a full service application (80 to 110 seconds for freight trains), the target information is displayed in the cab on the Compact Locomotive Display (CLD). Target information includes target speed, distance to target, time to penalty in seconds, and target type.

Operation

As trains move over the territory, the OBC logs on to each server as it approaches. This log-on process includes a verification of the track database version against a reference maintained at the server, to assure that the train is not working with a corrupted or obsolete database. In the process, the server also sends the OBC the current Temporary Slow Order (TSO) file. Temporary slow orders are created at the dispatch location and transmitted to the appropriate servers over a land-line equivalent called the Office-Wayside Link (OWL). At the server, any current TSOs are compiled into a special TSO file that is delivered to each approaching train when it logs on to that server.

For any active grade crossing so identified on the profile, the OBC continually calculates the expected time of arrival at the crossing (calculated as seconds remaining before arrival). When this time for any given crossing has reduced to about 100 seconds, the OBC transmits its arrival time estimate at the specified crossing. The server receives the message, arms the crossing to prepare for activation, and sets a delay timer to hold off activation of the crossing until the estimated arrival time has reduced to around 40 seconds. When all this is accomplished, the server then broadcasts the crossing status as armed and ready for hi-speed operation. When the delay time has expired, the server activates the crossing over the WLAN. Any loss in communications will either result in the crossing being activated prematurely, or in the train being given a reduced speed target at the beginning of the normal crossing approach so that full warning time will be obtained using the conventional start mechanism. Crossing health is also monitored at each crossing, so that a detected false activation will result in all approaching trains being given a target speed of 15 MPH at the crossing.

Train locations are not reported routinely from train to wayside, as this information is not required by the system. Targets are not based on reported locations of other trains but on signal locations and the indications displayed on each signal. Wayside signals could theoretically be removed but the fixed block location would still represent a target location, and an implied indication of an equivalent or Avirtual@ signal would still be employed as the basis for determining target speed at that location.

The OBC in effect defines its authorities based on the signal indication statuses it receives from the server. This status information is received on a frequent refresh cycle of approximately every 6 seconds. Failure to receive one broadcast has no immediate effect on the operation, but if three consecutive broadcasts are missed, the OBC assumes communications failure and begins a default routine that calls for reduced speed operation until communications can be restored. If ITCS is cut out (e.g. fails enroute), the train may continue at reduced speed and is still protected against possible violation by other equipped trains. In other words, a train with a failed ITCS on-board systems does not become invisible to equipped trains.

Protection of roadway workers is accomplished by the use of TSOs in the work areas. A TSO with a speed limit of 0 mph amounts to a track block applied in the exact area under authority of the roadway work authority.

Applicability to Passenger and Freight Railroads

ITCS is readily applicable to both freight and passenger service. In passenger service, ITCS is an economical approach to raising the maximum authorized speed above 79 MPH. It does this by 1) providing a fail-safe control system to satisfy Federal regulations concerning operation at 80 MPH and higher, 2) providing the additional braking distance required for operation at higher speeds without moving any signals or adding any aspects, and 3) providing adequate highway crossing warning times for higher speeds without changing any of the existing crossing start locations.

Not to be overlooked is the fact that freight carriers can use this system as well. Consider a heavily used freight line in which some form of PTC is deemed advisable and installation of electronic track circuits and continuously welded rail and elimination of pole line has resulted in a very reliable signal system with years of economic life remaining. ITCS item (1) above could become a possible solution. Also, if it is desired to operate some freight trains at say 70 MPH over a line currently signaled at 50 or 60 MPH, ITCS items (2) or (3) above will be able to accommodate this improvement without moving any signal or crossing start locations.

Deployment

ITCS is expected to be ready to deploy by mid-1999 and should have six months in service experience on the first 20 miles in Michigan by the end of 1999, and less experience on another 50 miles by early 2000. All of the essential features of ITCS have been successfully demonstrated up to 100 MPH. The supplier is now working through the safety process to ensure that all the safety-critical features will be safely executed under all possible combinations of failure modes.

Amtrak Advanced Civil Speed Enforcement System (ACSES) Project

Introduction

ACSES is a transponder based system overlaid on the existing continuous coded cab signal system in the Northeast Corridor (NEC). This system will enforce absolute stops, permanent and temporary speed restrictions, and protection for roadway workers.

The basic four-aspect continuous coded cab signal system has served the Northeast Corridor very well since the 1930's. The initial concept of feeding several simple codes to the front end of the train through the rails, with 60 years of hardware improvements, and with the addition of speed control starting in the early 1950's and mandated for all trains in the late 1980's, now protects the mix of inter-city (110 MPH), commuter (100 MPH), freight (50 MPH), and Metroliner (125 MPH) services extremely well.

The four-aspect cab signal system is based on 3 code rates (75, 120 and 180 pulses per minute (PPM)) providing four speed commands (20 MPH with no code, 30 MPH, 45 MPH and 80 MPH respectively). This system has been stretched to the limit as the maximum authorized speed has been raised from 80 MPH (1930's to mid-1950's) to the 125 MPH operation by the Metroliner service today. Now with further raising of the maximum speed to 150 MPH to accommodate the arrival of the new High Speed Trainsets (Acela Express Service), the nine-aspect system has evolved from the four-aspect system to "fill the gap" between 45 MPH and 150 MPH. This has been done by adding a 250 Hz carrier to the existing 100 Hz carrier, and by adding 270 PPM to the existing 75, 120 and 180 PPM code rates. The 250 Hz carrier allows immediate upgrades involving speeds of 80 MPH, 125 MPH and 150 MPH anywhere in the corridor (up to seven aspects) for those vehicles equipped to read the new composite (dual carrier) codes. The utilization of the 270 code (providing 60 MPH and 100 MPH speeds) has to wait until all vehicles operating in a particular area have been equipped to read the additional codes. Currently the 270 code rate is being installed only between New York, NY and Newark, NJ where only Amtrak and New Jersey Transit trains operate, and where all trains will be equipped with the full nine-aspect system. The 270 code rate will be available for future 60 MPH crossovers and for capacity improvements in heavy commuter areas.

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Discussion

This progressive expansion of the existing cab signal and speed control (ATC) system is the key to interoperability for all the users in the Northeast Corridor as Amtrak migrates to 150 MPH high speed service. Large improvements in headway (capacity) and the ability to enforce all turnout speeds (including the new 80 MPH turnouts) can be obtained by investment by individual users anywhere in the corridor without adversely impacting other users. Amtrak is using this structure to advantage in achieving intercity trip time goals, but others are also investing heavily in portions of the Corridor to achieve their own goals. A good example of this is New Jersey Transit=s heavy investment in the New York to Elizabeth, NJ portion of NEC to improve capacity and to provide new stations and services. This structure of the expanded ATC is facilitating these improvement programs.

By expanding on the very simple communication methods (through the rails) proven by long experience in the industry, the needs of all the users of the NEC are being met. Capacity requirements are being met by a combination of shorter blocks and additional codes which approach the much more expensive and elusive Amoving block@ capacities in the limit. This technology is available right now, off-the-shelf, proven, ready to install. All new on-board and wayside components take advantage of the latest microprocessor technology while functioning seamlessly with older electronic and relay systems that still have years of economic life. This approach in the NEC is also confirmed by the continuous cab signal systems used in the most modern high speed rail systems in France, Italy and Japan, for example.

While the expanded ATC described above meets nearly all the objectives of the 150 MPH high speed train service in this congested corridor, there are two things that even the expanded ATC does not do. ATC does not enforce curve and other civil speeds well, nor does it enforce positive stops at interlocking home signals. These two objectives are being met through the introduction of another well-proven technology, a transponder-based system from Western Europe. This system has its roots in Sweden in the 1950=s and is now used very successfully in a number of countries around the world. This technology is the basis for ACSES which overlays the ATC described above.

ACSES is able to precisely pinpoint the beginning and end of civil speed restrictions by providing distance to target and controlling grade data through transponder Atelegrams@. The on-board computer is able to construct a braking curve from the transponder data which will enforce all civil speeds in 5 MPH (or even 1 MPH) increments. This same type of transponder data is also used to pinpoint interlocking home signals to enforce positive stops at these signals. This is done in conjunction with the ATC in some scenarios and in conjunction with a MCP data radio in others. There are also some auxiliary functions outside the realm of train control which are accomplished in the same way, such as tilt enable/disable and supervision of propulsion controls through phase and voltage change breaks in the catenary.
Maintenance-of-Way work (and roadway workers) in the multiple-track Northeast Corridor

are normally protected by vital exit blocks at the interlockings at each end of the track involved. These exit blocks prevent the display of any aspect other than AStop Signal@ into the work area. ACSES will supplement the current protection provided by wayside signals and ATC by enforcing a positive stop at the interlocking home signals. Temporary speed restrictions will be enforced by temporary transponders initially, to be followed by the development of a data radio network which will deliver the temporary speed restrictions directly from the dispatcher=s office to each train.

Applicability to Freight and Passenger Service

Cab signals and speed control (ATC) currently protect all of Amtrak=s operations between Washington, D. C. and Boston, MA. This congested multiple track Northeast Corridor operates over 455 route miles with 2,3,4,5 and 6 tracks in different line segments, currently totaling 1150 track miles, and with additional main tracks being added and planned as intercity and commuter traffic continues to build. All trains operating in this corridor, including many freight trains, must be equipped with full ATC, i.e. both cab signals and speed control. There are many other corridors connected with the NEC equipped with ATC, such as: Philadelphia to Harrisburg[1] and Pittsburgh, Harrisburg to Perryville, MD, New York to Albany[1] and Schenectady, NY, Albany to Boston, MA, New Haven to Springfield, MA[1], Philadelphia to Atlantic City, NJ[1], Washington, D.C. to Richmond, VA[1]. Freight trains operate over many of these lines, and those trains are equipped with cab signals. ATC and speed control are used on many commuter lines as well.

Deployment

ACSES is currently being installed on 515 track miles of the NEC with a similar system to be installed on the contiguous commuter lines of New Jersey Transit (described in more detail on page C-36). Over 1000 miles are currently set to be installed with the expectation that the system will spread rapidly throughout the NEC and some of the connecting lines in the next 5 to 10 years.

BNSF TrainGuard™ Pilot Project

Purpose of Pilot Project

The Burlington Northern and Santa Fe Railway and WABCO Railway Electronics. are conducting a second pilot test of the TrainGuard™ system in southern California. This second pilot is being conducted over a more rigorous terrain and with substantially more traffic to thoroughly test the systems capabilities and capacities in the mainline railroad operations.

[1] Speed control must also be used on these lines

The project expands on the successes of the prototype and will extend to roadway worker equipment, demonstrating its ability to notify a roadway worker crew of an approaching train and to notify the train that is intruding on a work gang.

Scope of Work

The pilot project will consist of eight locomotives equipped with Train Guard™ system hardware operating in full revenue service. These locomotives will constantly broadcast their locomotive ID, location and speed so that when another equipped locomotive gets within range they will be made aware of each other's presence on a color graphics display.

Two roadway worker vehicles will also be equipped and monitored to determine their visibility to the trains in the area.

This test will cover roughly 200 miles of BNSF mainline track and 100 miles of foreign trackage rights. This will demonstrate that if locomotives are commonly equipped, interoperability between railroads is automatic.

Functions of System

TrainGuard™is an overlay Positive Train Control system designed to prevent trains from intruding on other trains and work crews by alerting the engineer to potentially dangerous situations in the vicinity. The TrainGuard™ system currently uses the End of Train (EOT) radio to broadcast the locomotive's unique ID, its location, and its speed to anyone in the area. In prototype tests, the radios demonstrated a range of 3.5 to 7 miles so that anyone in the area (trains, roadway workers, etc.) will know that a train is approaching.

The main philosophy of the TrainGuard™ system is that by providing the engineer with improved location information and by keeping him alert to potential dangers such as other trains and roadway workers nearby, he will take preventive actions to avoid collisions. If he does not, the on-board computer will bring the train to a stop.

TrainGuard™ uses a combination of GPS, the train's tachometer, a gyroscope, and an on-board track database to determine its location. The initial pilot test of the TrainGuard™ system was over a relatively simple track structure having a single main track with sidings. The Southern California pilot track is significantly more complex with two main tracks and crossovers splitting off into single main line with sidings south of Los Angeles.

The track database will be maintained in a central location and distributed to the locomotives on an as needed basis. This database contains the grades, curves, mileposts, civil speed restrictions, road crossings, switch locations, etc. and is used to determine and display the train=s location and its current stopping distance.

Details of the train consist will be input into the on-board system and stored on-board the locomotive. This information is used to determine stopping distance and speed restrictions.

An on-board computer does all of the calculations regarding stopping distance and enforcement. TrainGuard™ supports all of the core features of Positive Train Control as defined by the RSAC process but does not directly enforce violations of authority. TrainGuard™ does predictive calculations regarding collisions and will stop the train to avoid collision. Violations of speed restrictions are also enforced.

The pilot test being conducted in Southern California will include the development of a roadway workerTrainGuard™ device that will work in conjunction with the locomotive version. This will give roadway workers advance notice of a train=s arrival into their work area and advise the engineer of roadway workers in the proximity, independent of their limits of authority.

Currently TrainGuard™ is a proprietary system but discussions are underway to facilitate the integration of TrainGuard™ into other architectures. TrainGuard™ could serve as a foundation for many other systems providing fundamental interoperability.

Passenger / freight applicability

Nothing in the design of TrainGuard™ specifically limits its applicability to passenger or freight operations. As with all PTC systems the speed of passenger trains puts a burden on the communications platform and must be accounted for in the selection.

Technical readiness

TrainGuard™ is currently in pilot testing on a second corridor. The results of the first pilot were very successful. A very similar system from GE-Harris is in daily operation on the Quebec North Shore & Labrador Railroad in Quebec, Canada.

Conrail/Norfolk Southern/CSXT Positive Train Control Pilot Project

Introduction

This section describes a communication based train control system with the objective of providing interoperability between railroads, open architecture and a standard message structure. This is a technology independent approach accommodating all present and future train control technologies.

Scope of the PTC System

The overall positive train control system could be simple, such as, manual entry of track warrants received by voice radio into an on-board computer, triggering warnings or enforcement for non-compliance or complicated, such as a completely automatic train control system involving wayside or central office based logic. The PTC system takes into account the flexibility needed to operate over the different territories seamlessly, because the three railroads have significant differences in infrastructure and the test corridor itself has four types of existing train control.

Although it would be desirable, it is clear that there will not be a unified PTC system installed among all the freight or passenger railroads in this country. The ability to run through different types of train control territory whether they are on one railroad or between railroads has become increasingly important. It is not always acceptable to stop trains and add equipped locomotives between those territories.

Pilot Objectives

The program objectives for the Conrail/NS/CSX pilot are:

- To improve safety by providing enforcement within existing systems
- To develop standard on-board platform to achieve interoperability with minimum cost.
- To provide a practical migration path from existing systems

Program Overview

The PTC pilot is planned in two phases. Phase I includes the design and prototype of the on-board PTC platform. The logical architecture for the on-board system is shown in Figure 1.

Phase II consists of the wayside and office components to provide PTC system(s) for the whole territory the on-board platform has to operate over.

On-Board System

The key feature of the on-board system is a LonWorks communications bus using the LonTalk communications protocol. A standard set of messages using a standard format have been developed.

The questions that will have to be asked and answered by the on-board unit are:

> Who am I?
> Where am I?
> What do I need to proceed?
> Do I have what I need to proceed?

The answer to those questions will be given by various objects depending on the territory the locomotive is running on. Figure C-4 depicts the core process concept graphically and Table 1 outlines the core functions in detail.

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The objects are physically or logically connected to the communications bus as individual units, but later production models will probably consist of combining several objects assembled into one unit. The communication bus will support safety critical messages for positive train control.

The core and non-core objects and modules are shown in Figure 3, core objects are depicted by the light boxes. All other objects are non-core and may be specific to a railroad or territory.

The on-board platform is designed to meet all objectives of the PTC program. On-board hardware and software will be decoupled and individual components can be safety certified independently from the bus. This will require the bus to only be safety certified for the handling of safety-critical messages.

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The bus capacity will be designed for expansion, allowing for additional objects and the introduction of new technology without system modifications. New objects or functions would communicate with the same basic messages and message structure. After sizing the on-board unit properly the on-board system can be incrementally implemented. The on-board unit has the potential to become the standard for the rail industry and existing systems can be connected to it through interfaces as long as the standard message set is used.

Phase II Wayside Installations

Since the PTC pilot will have to accommodate four different existing train control systems it is easily conceivable that it will not be one system. The pilot attempts to take advantage of the existing infrastructure and the inherent vital logic that is already incorporated in the present systems. Migration and the economics of a train control system will dictate how rapidly one railroad may advance from a simple system of entering train orders to the final completely automatic system. The on-board platform will allow for migration and be able to accommodate various systems. In signaled territories, signal information may be received via data communications from the wayside or a transponder connected to the wayside. A central office system with a communications infrastructure can also be accommodated. Cab signal systems can be enhanced by location information, making enforcement of absolute stops possible.

Test Corridor

The PTC corridor for Conrail/NS/CSX pilot is as follows:

Program Overview Territory Description

- The Conrail Pittsburgh Line
  - 5 miles Cab Signal & TCS
- The Conrail Lurgan Branch
  - 35.5 miles TCS, 4.5 miles ABS
- The Conrail Hagerstown Secondary
  - 33.5 miles presently not signaled
- The NS Virginia Division AH@ Line
  - 70 miles TCS signaling

- The NS Piedmont Division AB@ Line
  - 45 miles presently not signaled

- The CSXT Spartanburg Subdivision
  - 90 miles presently not signaled

- The CSXT McCormick Subdivision
  - 30 miles presently not signaled

Summary

The Conrail, Norfolk Southern and CSX Transportation pilot represents a comprehensive PTS/PTC project that can be applied to passenger as well as freight lines, part of the test corridor from Harrisburg to CP Rockville has passenger traffic.

The project is currently in the on-board unit prototype phase. Two prototypes are being contracted for in 1999. Work on an active PTC will be developed and tested in 2000.

In that there are no current PTC/PTS Systems in revenue service among Class I railroads in the US, technical readiness can only be assumed and the pilot is designed to evaluate for the feasibility of deployment of a communications based system and a migration path that is economically achievable.

Industry/FRA/IDOT PTC Project

The Association of American Railroads (AAR), the Federal Railroad Administration (FRA), and the Illinois Department of Transportation (IDOT) have entered upon a joint program to design, build, test, and install a Positive Train Control (PTC) system on a 123 mile section of the Union Pacific Railroad from Springfield to Mazonia, Illinois. The Program will develop and recommend a set of PTC interoperability standards for industry adoption and long term maintenance, and will demonstrate application of these standards in the IDOT pilot installation.

The Program participants have agreed that the AAR=s subsidiary, the Transportation Technology Center, Inc. (TTCI) will serve as prime contractor for the effort. TTCI has responsibility for overall program design, management, and administration. A Management Committee made up of railroad representatives and financial sponsors (AAR, FRA and IDOT) reviews technical and contractual decisions. Final responsibility for Program funding rests with a AStakeholders@ Committee comprised of senior representatives of the financial sponsors.

The Joint Program PTC standards and the pilot implementation in Illinois will meet overall safety objectives derived from a consensus labor-management-vendor-government discussion process sponsored by FRA and lasting over many months. This activity is called the Railroad Safety Advisory Committee (RSAC) PTC Working Group.

PTC Joint Program Design and Management Requirements

In addition to developing PTC standards and a service-ready demonstration system that will both comply with the industry standards and meet the RSAC safety objectives, the PTC Joint Program has agreed on several other project requirements:

2.1 The Program=s PTC design will incorporate flexible block operations and advance activation of highway grade crossing devices, in a corridor with both freight and high speed passenger service (up to 125 mph).

2.2 A major program goal is to achieve interoperability of PTC systems from different manufacturers, installed in different types of locomotives, and operating over different kinds of signal control territory. The program will demonstrate safe operation of locomotives equipped with interoperable systems. The objective is to enable equipped trains operating from different railroads to come onto a foreign railroad at track speed. The demonstration will consider:

3. Locomotive human-machine interfaces with a minimum set of standard features, to provide the necessary and expected information for safe operation.

4. Compatible communications interface(s) to/from and on board the locomotive.

5. Minimum acceptable content and format of data bases used for location determination and braking enforcement'

6. Minimum common set of messages between defined devices and objects (functions) on board the locomotive/track vehicles and off board controllers.

3.3 An overriding program goal is to provide a cost-effective design and to support logical market-based migration strategies. The system should be modular and flexible enough to enable railroads with varying levels and types of current infrastructure to develop incremental deployment plans consistent with their system safety improvement plans.

4. The National Transportation Safety Board (NTSB) has called for nationwide PTC deployment and FRA has considered using its regulatory powers to mandate PTC installations in what it considers higher risk corridors. The railroads strongly believe that, since PTC has not been shown to be cost-effective on safety benefits alone, the modular, infrastructure-specific approach -- taken within the context of overall capital and safety improvement plans -- is a superior policy.

5. The railroads argue that without interoperable standards, cost-effective systems are impossible; without cost-effective systems, wide scale deployment is unlikely; and without wide scale deployment, few safety benefits will be realized.

The IDOT PTC Joint Program will implement these overall objectives and design requirements through contracts with system engineering companies. Contracts with the systems engineering firms will spell out detailed tasks and work-breakout structures. Examples of scope of work items included in the engineering contracts follow:

2.1 Develop a set of recommended industry standards to enable interoperation among companies and territory types **B** recognizing that not every extant signal system or territory type can be accommodated at reasonable cost.

2.2 Develop, test and evaluate a PTC system, initially on the Union Pacific=s Springfield subdivision from Springfield to Mazonia, to meet the program objectives.

2.3 Establish and document procedures to be used for the validation (did I build the right thing) and verification (did I build the thing right) of the safety system hardware and software, and complete the verification and validation process for this program.

2.4 Provide for field and simulation testing of systems for performance to PTC specifications and interoperability standards.

The PTC Joint Program is being conducted under the following overall terms and conditions:

2.1 The Transportation Technology Center Inc. (TTCI, a subsidiary of the AAR) will administer the PTC Program.

2.2 Standards and architecture developed and adopted will be open and non-proprietary.

2.3 Major Program procurements will be competitive.

2.4 Specifications will be driven by functional and performance requirements, not specific products or technologies.

2.5 PTC software developed or procured through PTC Program contracts will be made available for the improvement of railroad safety and operating efficiency to the greatest extent reasonable.

2.6 The program may be expanded beyond its original scope by mutual agreement of the parties.

Funding, Period of Performance, and Deliverables

[illegible]

Systems Requirements and Functional Architectures

The PTC Program has selected a System Engineer team headed by ARINC of Annapolis, Maryland. The System Engineer will assist the PTC Program staff and Management Committee in defining system requirements and developing the functional architectures (designs) that form the foundation for the remainder of the program. In particular, this work item will:

7. Set the tone of the PTC project's relationship with the supplier and railroad community through key industry meetings and forums;

8. Establish the level of supplier participation in and support for the PTC program through the degree to which proffered requirements documents and system architectures are fairly and impartially considered;

9. Continue to build and document a consensus among the program sponsors (IDOT, FRA, individual railroads, and TTCI) on the requirements for PTC (in general) and for testing and demonstration on the Springfield subdivision (in particular); and

10. Define PTC system architectures and interoperability standards that provide sufficient standardization while encouraging supplier innovation and supporting railroad-unique operations.

Interoperability Standards

One of the major objectives of this joint PTC program is to demonstrate safe operation of locomotives equipped with interoperable systems. Interoperability is currently defined as safely interlining at track speed. This definition implies more detailed requirements to achieve interoperability:

11. Standard, interoperable communications both to and from the locomotive;

12. Consistent format and content of databases (both on-board or off-board);

13. Standard messages between PTC devices, including standard content and format;

14. Defined expected responses to standard messages;

15. Minimum consistency of man-machine interfaces with recommended operating rules changes and training procedures;

16. Achieve safety objectives and cost effective performance requirements.

The System Engineer will develop interoperability standards through a process of workshop discussions and by reviewing current and proffered standards and specifications as well as applicable new technologies. The System Engineer will then draft proposed standards, which the PTC Program will sponsor through the AAR=s standards-setting committee structure. The Systems Engineer will also be responsible for configuration management of the interoperability standards for the duration of the project.

The PTC System Development and Demonstration for IDOT

The PTC Program Office, with assistance of the System Engineer, will issue a Request for Proposals (RFP) for selection of a System Developer/Integrator (SDI) in early 2000. The SDI will have responsibility for designing, fielding, testing, and documenting a PTC system that complies with draft AAR industry standards and meets the other performance objectives of the Program. The PTC demonstration test bed is a single track line with sidings between Springfield and Mazonia, Illinois, owned by Union Pacific Railroad and used for mixed freight service. The line also hosts passenger trains sponsored by IDOT and operated by Amtrak. The test segment is 123 miles long, is equipped with CTC, and has about one highway grade (level) crossing per mile.

The Springfield line is part of a proposed high speed passenger corridor sponsored by the IDOT and officially designated by the FRA under provisions of Section 1010 of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. Historically, this trackage was owned in turn by the Chicago and Alton; the Gulf, Mobile and Northern; the Gulf, Mobile and Ohio; the Illinois Central Gulf; the Chicago, Missouri and Western; and Southern Pacific. Upon completion of the UP-SP merger in October 1996, the line became the Springfield Subdivision of the Union Pacific. The line has been part of the premier passenger route between Chicago and St. Louis since the days of the Chicago and Alton.

IDOT proposes to reduce rail passenger travel time between the Chicago and St. Louis from the current 5 **2** hours to 3 **2** hours, and in this context wants the train control system developed by the Joint PTC Program to be revenue service-ready, not a demonstration-only installation. Since proposed passenger train speeds will reach 110 mph or more, IDOT requires the PTC on-board computer display equipment to meet the FRA requirement for in-cab signals at those speeds. Grade crossings will have to be closed or physical barriers placed in many locations over the route. Protected crossings must be given an advance start for faster trains in order to provide a constant warning time to motor vehicular traffic.

Reasons for Addressing Capacity Issues in the IDOT Design

While traffic congestion is not a problem on the Springfield-Mazonia line, freight railroads are concerned about potentially being asked to host higher speed passenger service on other freight corridors that may be operating near capacity already. Higher speed passenger service on well-used freight lines requires significant track capacity, due primarily to differential speeds for the two kinds of service. Differential speeds mean that opposing track (in double track territory) or sidings (in single track territory) must be used for faster trains overtaking slower ones. The effect on throughput capacity is $\square\overline{.5}\square 2\overline{)21500}\square\overline{500}\frac{1}{12}\frac{1}{10}$ to that of mixing automobiles and heavy trucks on a busy two or four lane highway through undulating countryside, especially when one truck passes another on a long uphill grade!

In mixed passenger and freight territory, passenger trains typically have dispatch priority, which means greater likelihood of delaying freight trains, especially as line traffic density increases. Track configuration (e.g., single vs. double track), additional sidings (siding spacing instead of additional sidings), type of signaling, and operating policies such as the differential in train speed are key factors in determining line segment capacity.

In general, the problem of capacity losses for freight operations due to passenger traffic is because the freight train has fewer operating channels (slots) to use in getting over the road, which implies more stopping and starting **B** hence poorer fuel economy and greater probability of delays.

Implications for Capacity of Train Control Systems Design

There are significant implications for throughput capacity in design and implementation of train control systems. Just as more capable signaling systems were installed in the past primarily to increase capacity while maintaining safe operations, so would cost-effective, safety-enhancing train control be more likely to be deployed if it is shown that expected capacity improvements truly can be realized.

With respect to train control features, it is likely that well-designed moving (or *dynamic*, or *flexible*) block architectures will have greater ability to increase capacity than fixed block systems. Moving block architectures are particularly applicable in circumstances of: 1) dense traffic, where closer headways reduce the time interval needed for safe physical train separation, 2) differential freight and passenger train speeds, and 3) recovery from service interruptions or maintenance curfews, when fleeting or other special operations may be used.

Capacity analysis is a controversial area in railroad research because of the difficulties of allocating common costs and establishing the cause and effect relationships between capacity or throughput increases and specific capital or operating improvements. Operations simulation is probably the most useful analytical technique for estimating capacity related consequences of major changes in plant, equipment, or operating practices on a specific line segment or network. For a specific application such as the Illinois 1010 corridor, operations simulation may be capable of establishing the capacity impact of such issues as: 1) operating freight and passenger trains at substantially different speeds, 2) the value of a dynamic block train control design, and 3) the contribution of specific physical improvements in conjunction with PTC.

System Test Requirements And Performance Measures

The System Engineer will design and deploy the testing methodologies and systems necessary to prove that the PTC system implementation on the Springfield subdivision has met all its design objectives. This includes developing tests for evaluating the compliance of Aforeign@ locomotives, developing both operational and technical performance measures for the overall system and subsystems, reviewing SDI specifications for compliance with system design requirements, and development of a concept of operations to guide the planning of laboratory and field testing. Moreover, a battery of tests will be developed to demonstrate that the PTC system is developed according to the interoperability standards and that it meets the requirements for the efficient operation of high-speed passenger trains operating over routes and facilities also used by freight trains. These tests will be designed to evaluate system safety-related and other functions, system reliability and maintainability, and degraded operation under failure conditions. In this effort the System Engineer will work with the SDI to:

17. Oversee all acceptance tests to ensure compliance with prescribed test plans'

18. Configuration manage changes in test plans that may be needed.

19. Maintain a log of all acceptance tests and reporting on their results to the Program Office.

20. Identify the cause(s) of failed tests and research possible solutions. In situations where minor software or specification changes are required, document the changes and create/update the test plans. In cases where the proposed solution is in conflict with the Joint PTC Program requirements or the industry standards, the System Engineer will document the issue, develop recommendations for changes, and progress the issue to the PTC Program Office for resolution. Once the proper authority has authorized a change, update all affected documentation and create/update test procedures as required.

Lastly, a proposed test plan for the evaluation of the Joint PTC Program equipped locomotives on other PTC territories will be developed.

PTC Simulation Tools

The PTC Program and the industry will need simulation tools beyond those used by the Systems Developer/Integrator, and beyond the duration of the PTC demonstration, to test systems performance under a variety of situations. The PTC Simulation Tools project involves designing and developing a PTC system simulation tester or suite of testers that might included the capability to==

Appendix C